Wave Properties of Matter Q.M. 1

Main Concepts

Wave-Particle Duality) — Idea of Bohr Correspondance works w/ size & temperature.

Probabilistic Interpretation

Uncertainty Principle

Wave Function, the "meaning" of matter waves, & Einstein Podolsky-Rosen proposal

5.2 De Broglie waves

$$\bar{\nabla}\times\bar{E} = -\frac{\partial \bar{B}}{\partial t}$$

5.1
5.3 } x-ray & electron diffraction

$$\bar{\nabla}\times\bar{B} = \mu\bar{J} + \mu_0\varepsilon_0\frac{\partial E}{\partial t}$$

1) Matter-energy & space-time "dualities"
2) Planck's Quantization hypothesis & P.E. effect
   $\Rightarrow$ Wave-particle "Duality" of Radiation
3) Bohr Model & assumptions of Quantizing L

Photon Energy

$E = h\nu \qquad E = pc$

$C = \lambda\nu$

$\Downarrow$

$h\nu = p(\lambda\nu)$

$\lambda = h/p$

De Broglie suggests that matter has a wavelength. (Matter sometimes acts like a wave)

Ex 5.2

λ_0 for a "Classical" tennis ball vs a Quantum Electron

Tennis Ball

$m = 0.06\ kg$
$v = 10\ m/s$

$$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}\ J\cdot S}{(0.06kg)(10\ m/s)} = 1.105\times10^{-37}\ m$$

Electrons

$K = 50\ eV$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{hc}{\sqrt{2mc^2K}} = \frac{hc}{\sqrt{2(0.5\times10^6 eV)(50\ eV)}} = 0.17\ nm$$

Ex 5.4

$T = 300K$

$$\langle K\rangle = \frac{3}{2}kT = \frac{p^2}{2m}$$

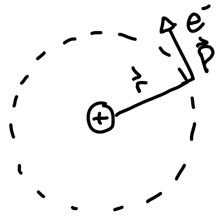
$$p = \sqrt{3mkT}$$

$$\lambda = \frac{h}{\sqrt{3mkT}} = 2.52\ m\cdot K^{1/2}\ \frac{1}{T^{1/2}}$$

$\lambda = 0.145\ nm \qquad T = 300K$

$\lambda = 0.287\ nm \qquad T = 77K$

Bohr's Quantization Condition:



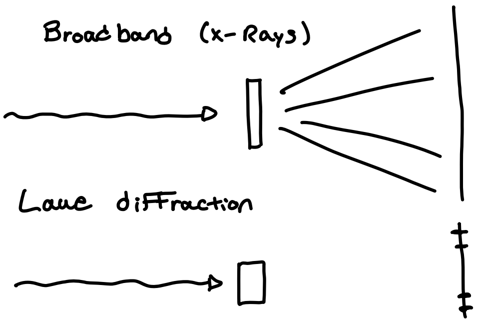
De Broglie says "Stationary States are standing matter waves"

$n\lambda = 2\pi r \qquad \lambda = \frac{h}{p}$

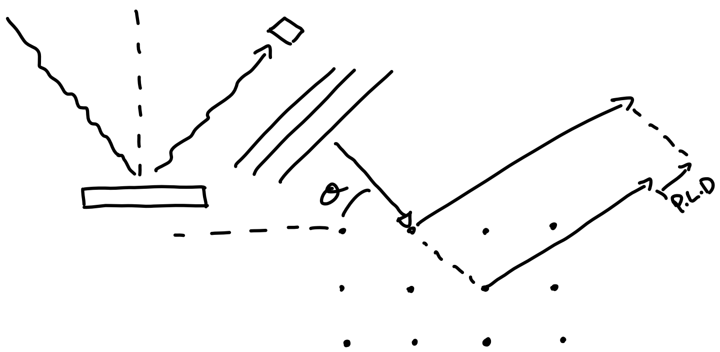
$\frac{nh}{p} = 2\pi r \Rightarrow r = \frac{n\hbar}{p} \qquad \hbar = \frac{h}{2\pi}$

$|L| = |r \times p| \Rightarrow L = rp = \left(\frac{n\hbar}{p}\right)p \Rightarrow L = n\hbar$ ← Bohr's condition

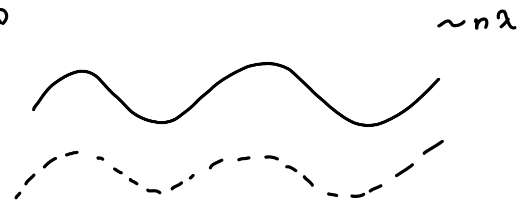
X-Ray Scattering



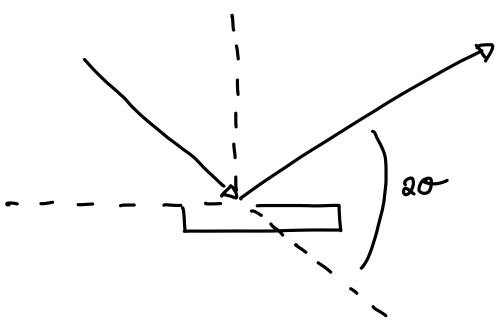
Pattern of Spots is regular and reflects underlying Crystal structure.



1) Angle of Incidence = Angle of reflection
2) $n\lambda$ = PLD for constructive interference



$n\lambda = 2d\sin\theta$



Ex: x-Rays Bragg Scattered from NaCl ($n=1$)

$\lambda = \frac{2d\sin\theta}{n}$

$2\theta = 20° \Rightarrow \theta = 10°$

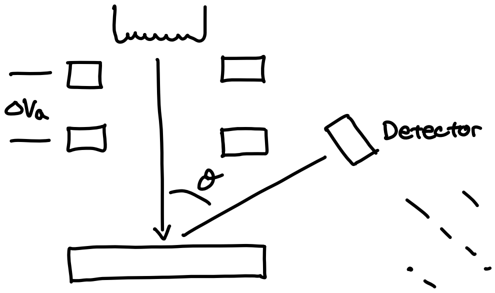
$\frac{\#\,\text{atoms}}{V} = \frac{N_A\,\rho}{M_m} = 4.5\times10^{22}\ \#/cm^3$

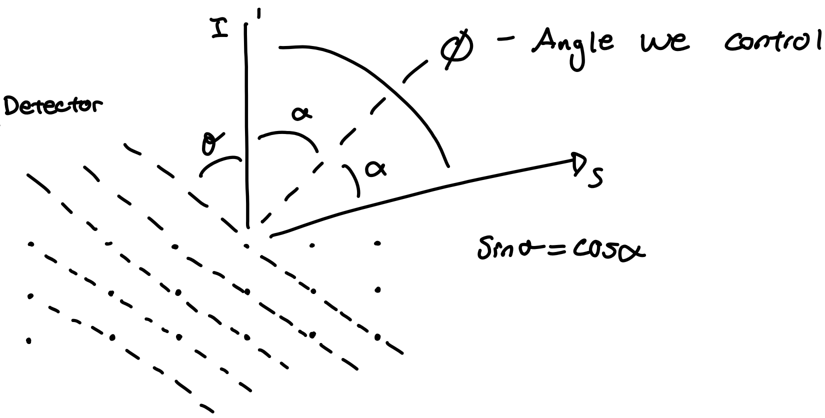
$N_A = 6.02\times10^{23}\ \#/mol$

$M_m = 58.5\ g/mol$

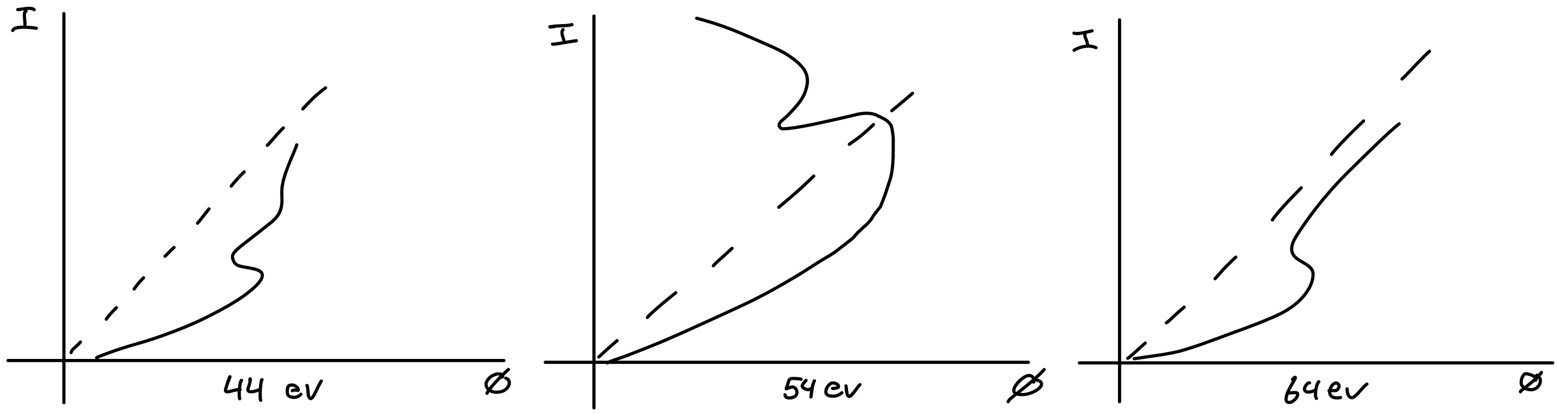
$\rho = 2.16\ g/cm^3$

$d = \sqrt[3]{V/\#} = 2.8\times10^{-10}\,m = 0.28\ nm \Rightarrow \lambda = \frac{2d\sin\theta}{n} = 0.097\ nm$





$\sin\theta = \cos\alpha$



$n\lambda = 2d\sin\theta$

$= 2d\cos\alpha = 2d\sin\alpha\cos\alpha = d\sin 2\alpha \quad (n=1)$

$= d\sin\phi$

$D = 0.215\ nm \qquad \lambda = \dfrac{D\sin\phi}{n} = 0.165\ nm$

$\phi = 50^\circ$